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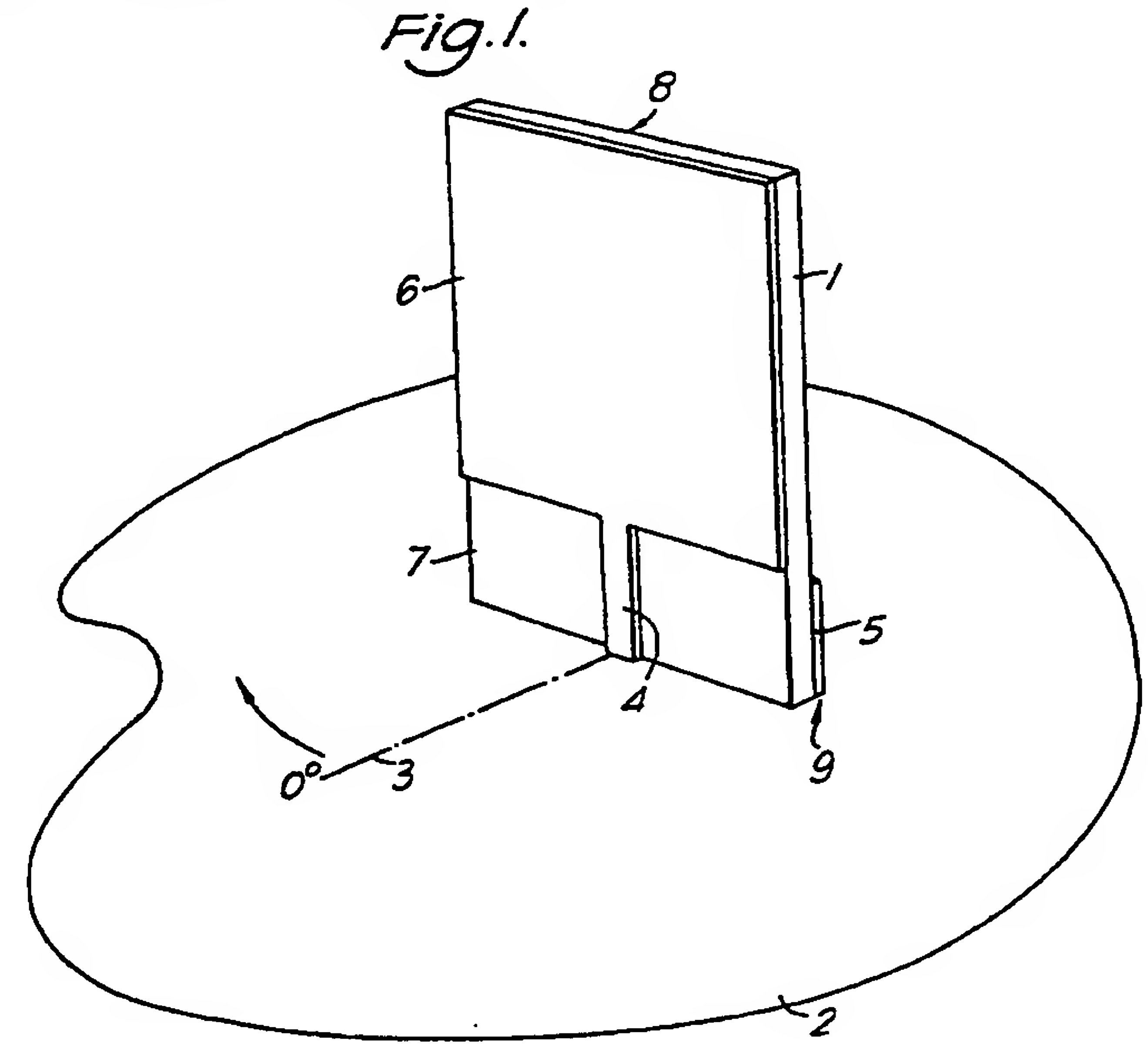
(54) **Monopole antenna**

(57) A broadband monopole antenna comprising a radiating element extending vertically with respect to a horizontal ground plane 2. The radiating element comprises upper 6 and lower 5 conductive sheets carried on opposite main faces 7, 8 of a dielectric substrate 1. The two sheets 5, 6 are separated by a narrow slot (10), Fig 2, parallel to the ground plane 2. The lower sheet 5 is connected along one edge 9 to the ground plane 2, whereas the upper sheet 6 is connected to a stripline feed 4 with which it forms a continuous conductive layer. The capacitance of the slot (10) at the feed point maintains a low input impedance for the antenna over a wide frequency range. The antenna produces radiation patterns substantially the same as a conventional monopole whip antenna, but offers a superior impedance match bandwidth in excess of 5:1 with VSWR less than 2.5:1. The antenna is conveniently fabricated using microstripline circuit board.

Fig.1.



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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Fig.1.

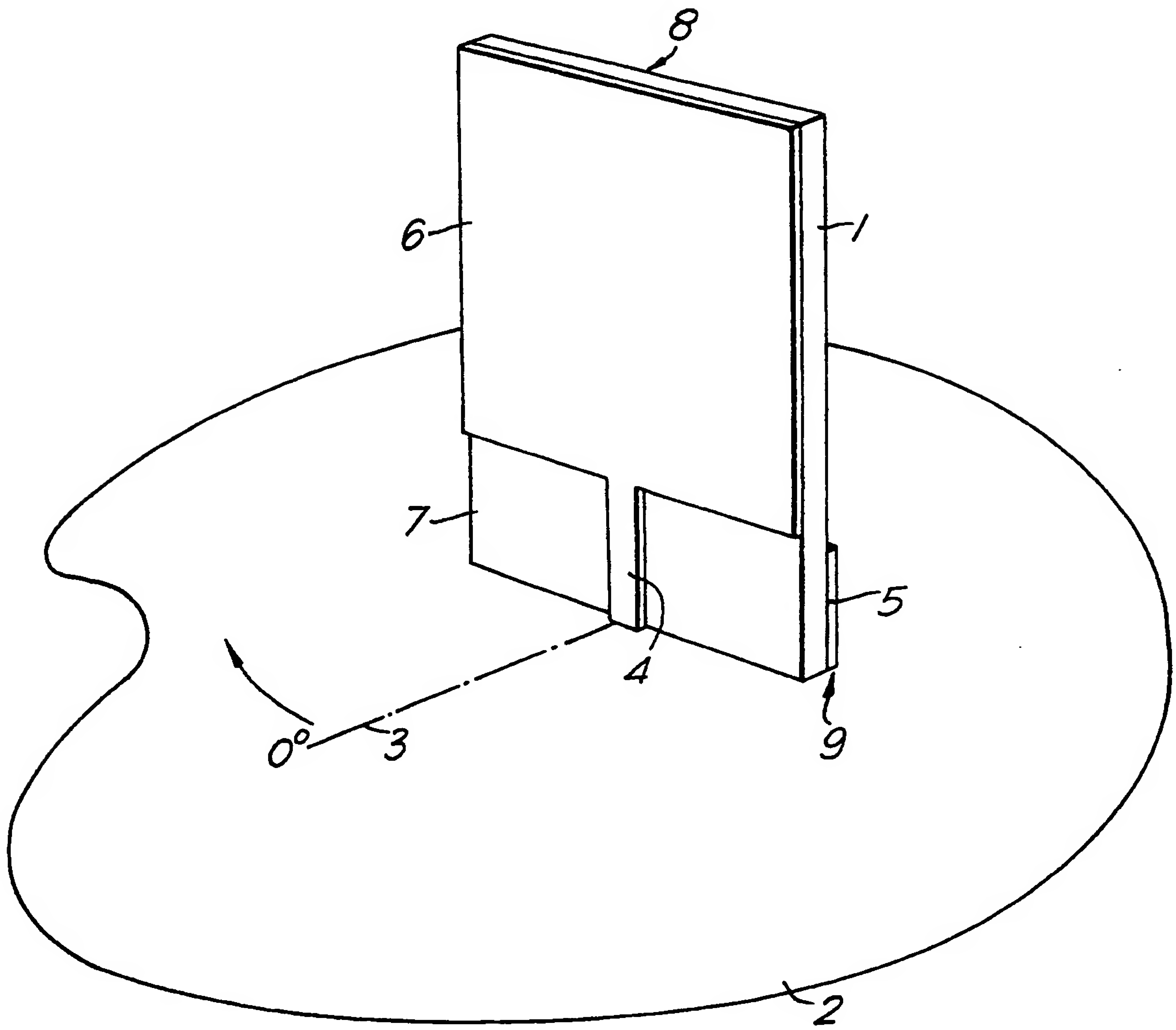


Fig.2(a)

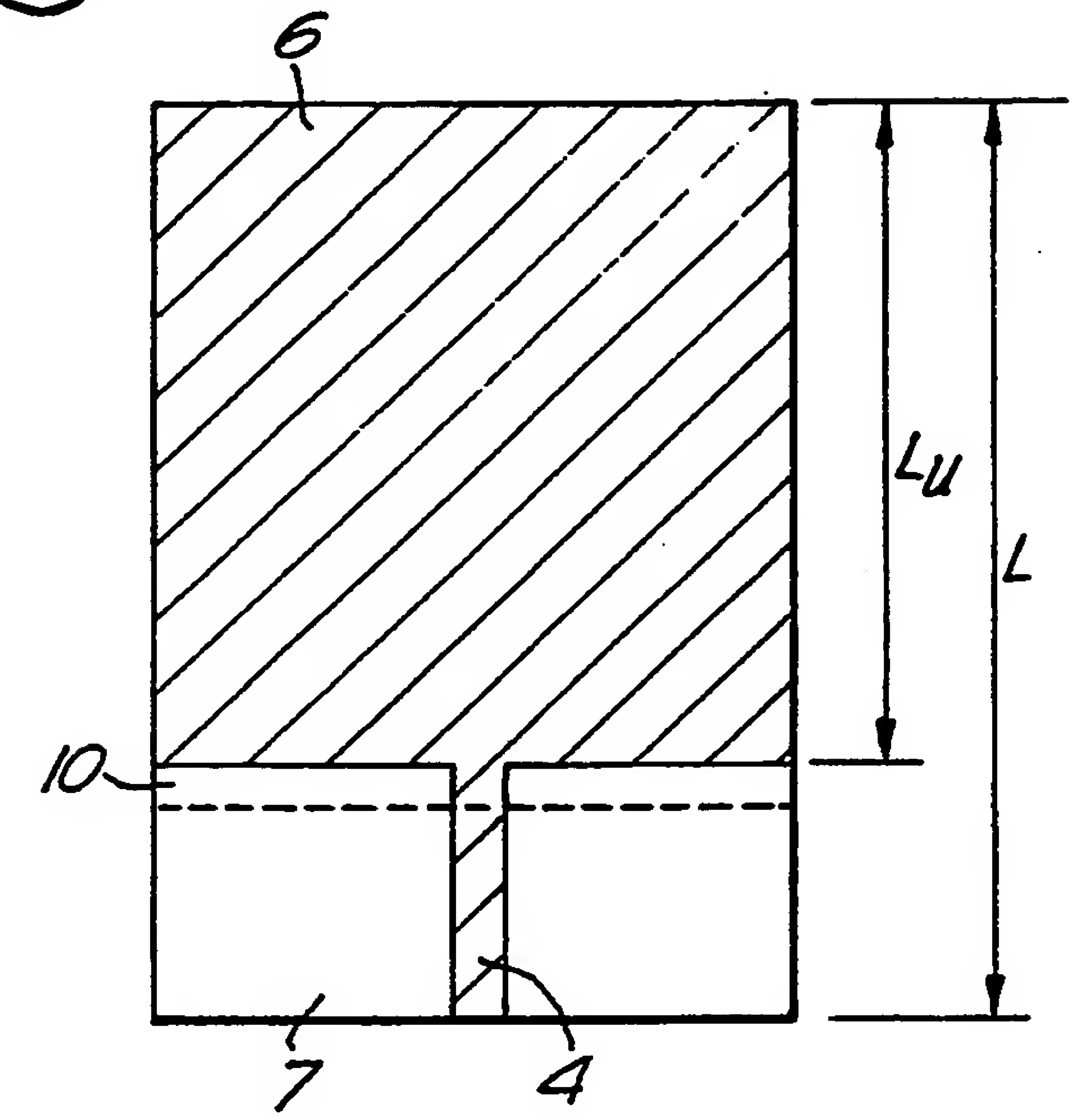


Fig.2(b)

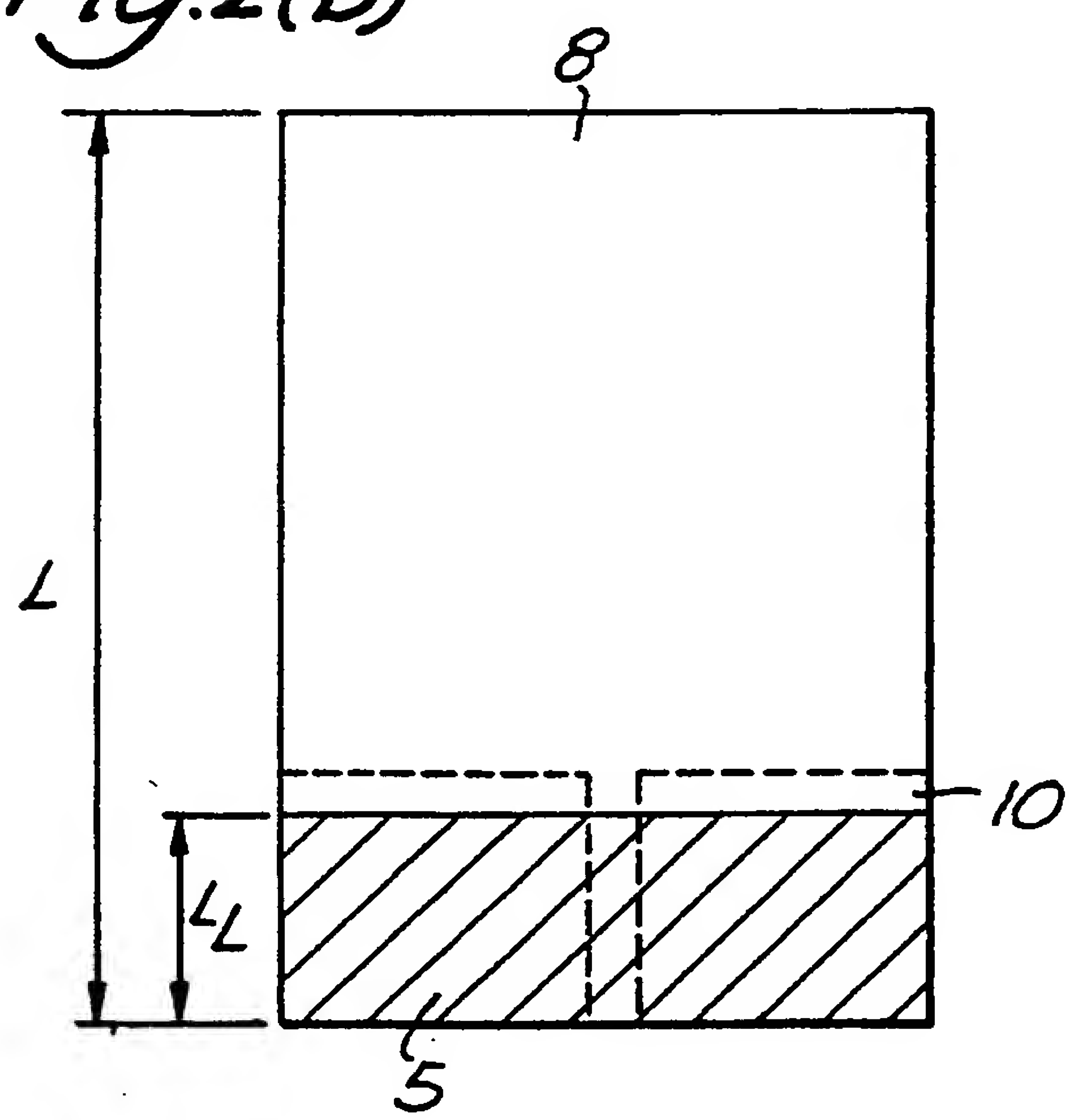
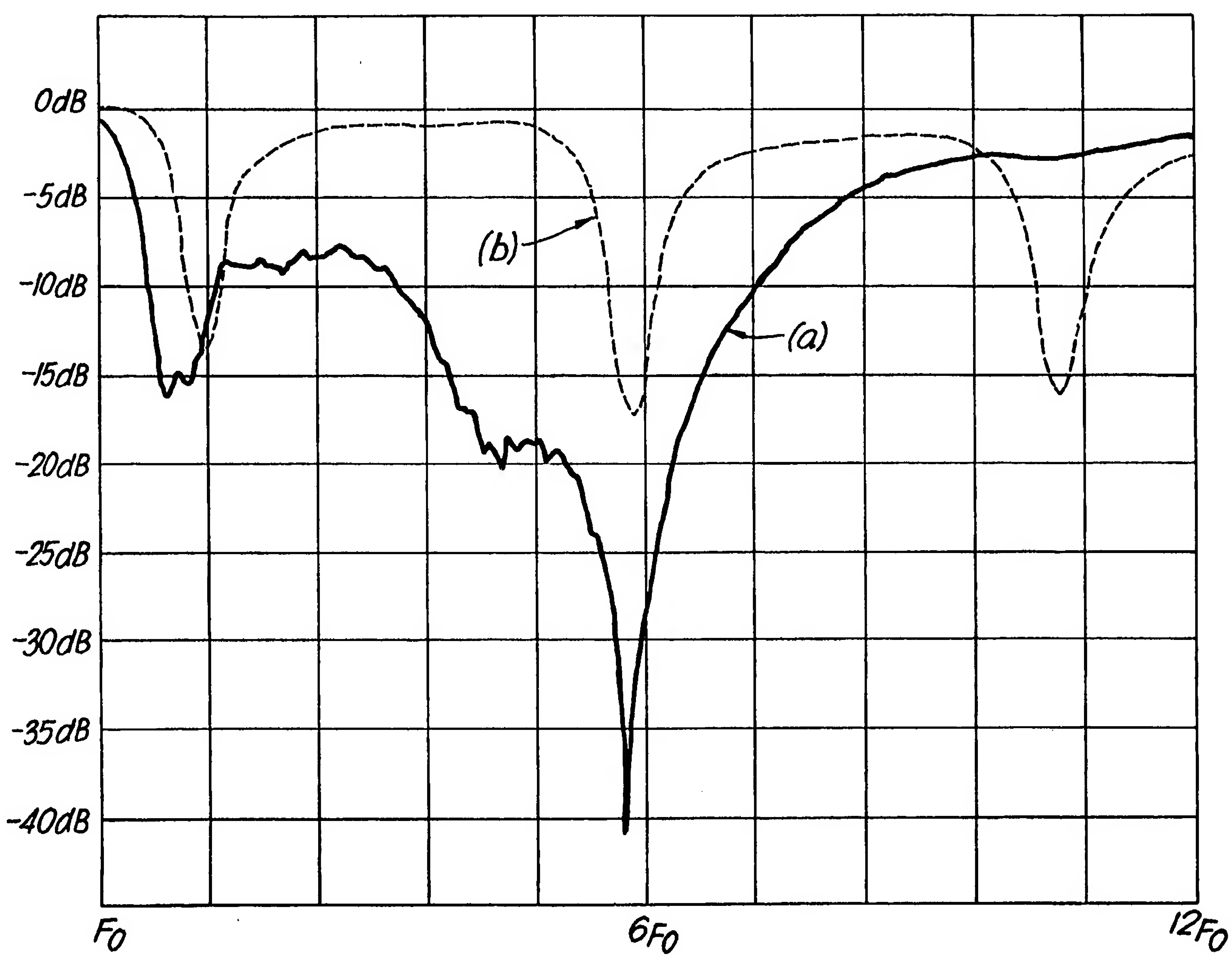
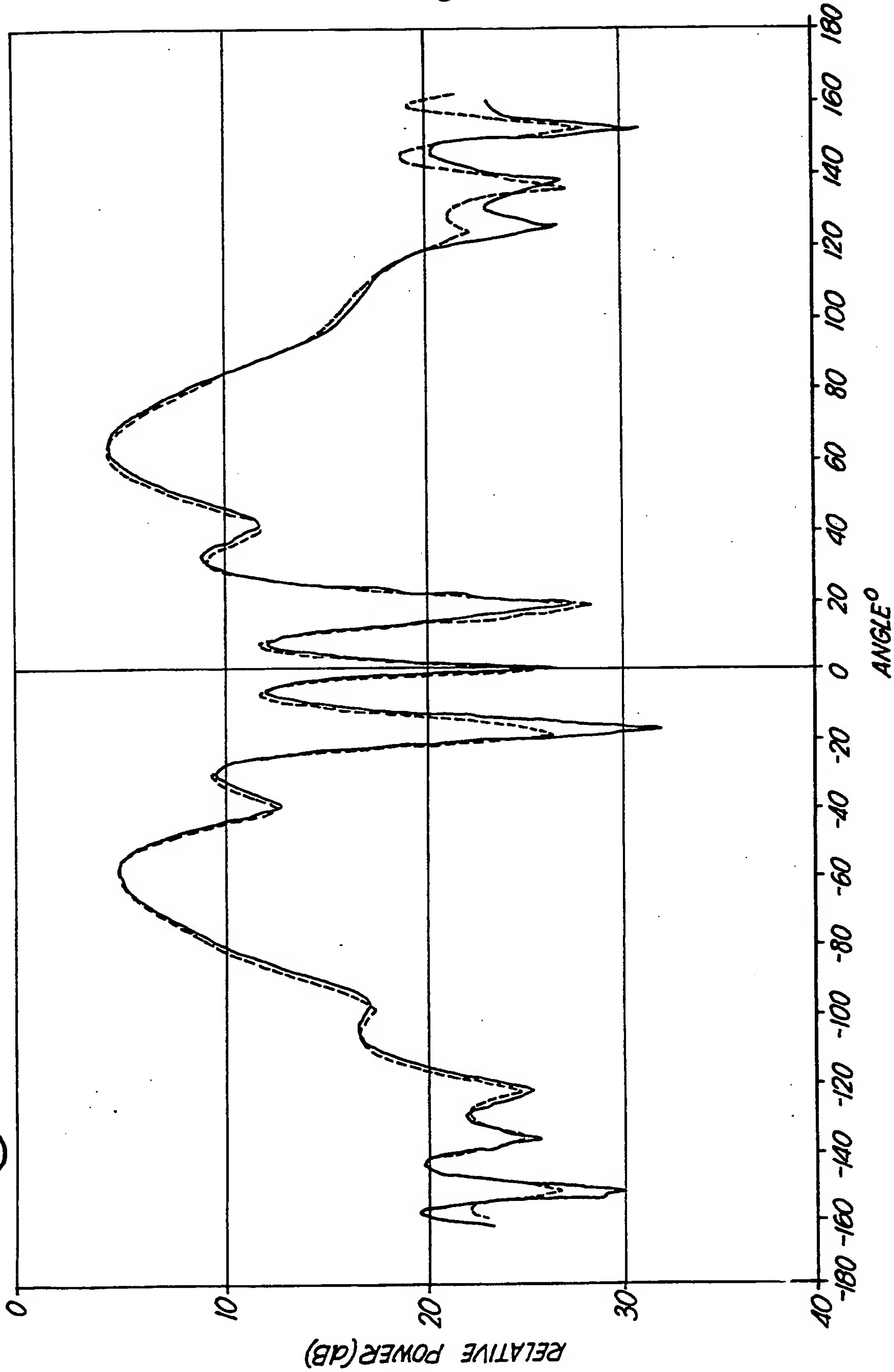


Fig.3.

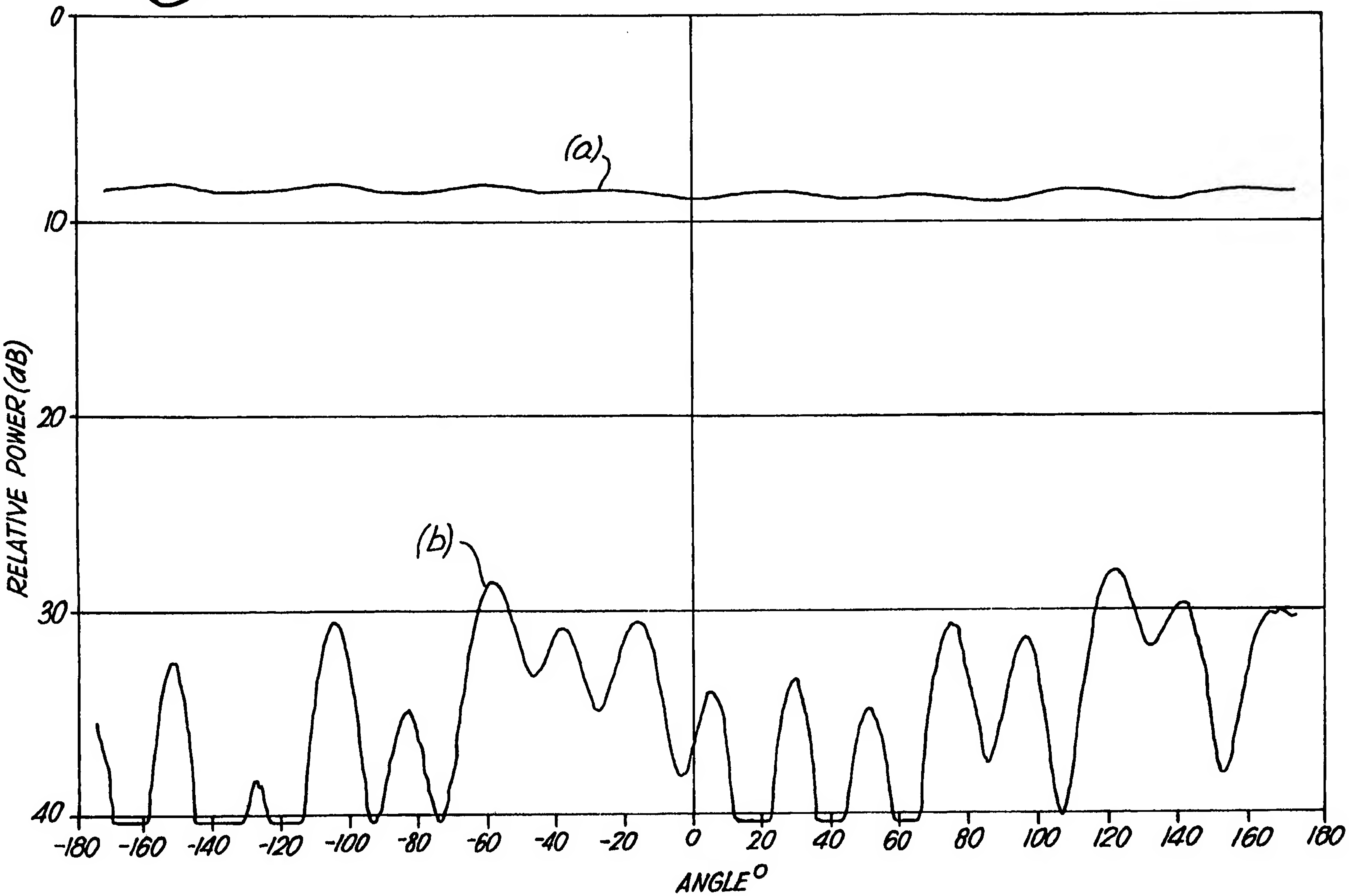




0
10
20
30
40
RELATIVE POWER (dB)
-180
-160
-140
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
120
140
160
180
ANGLE°

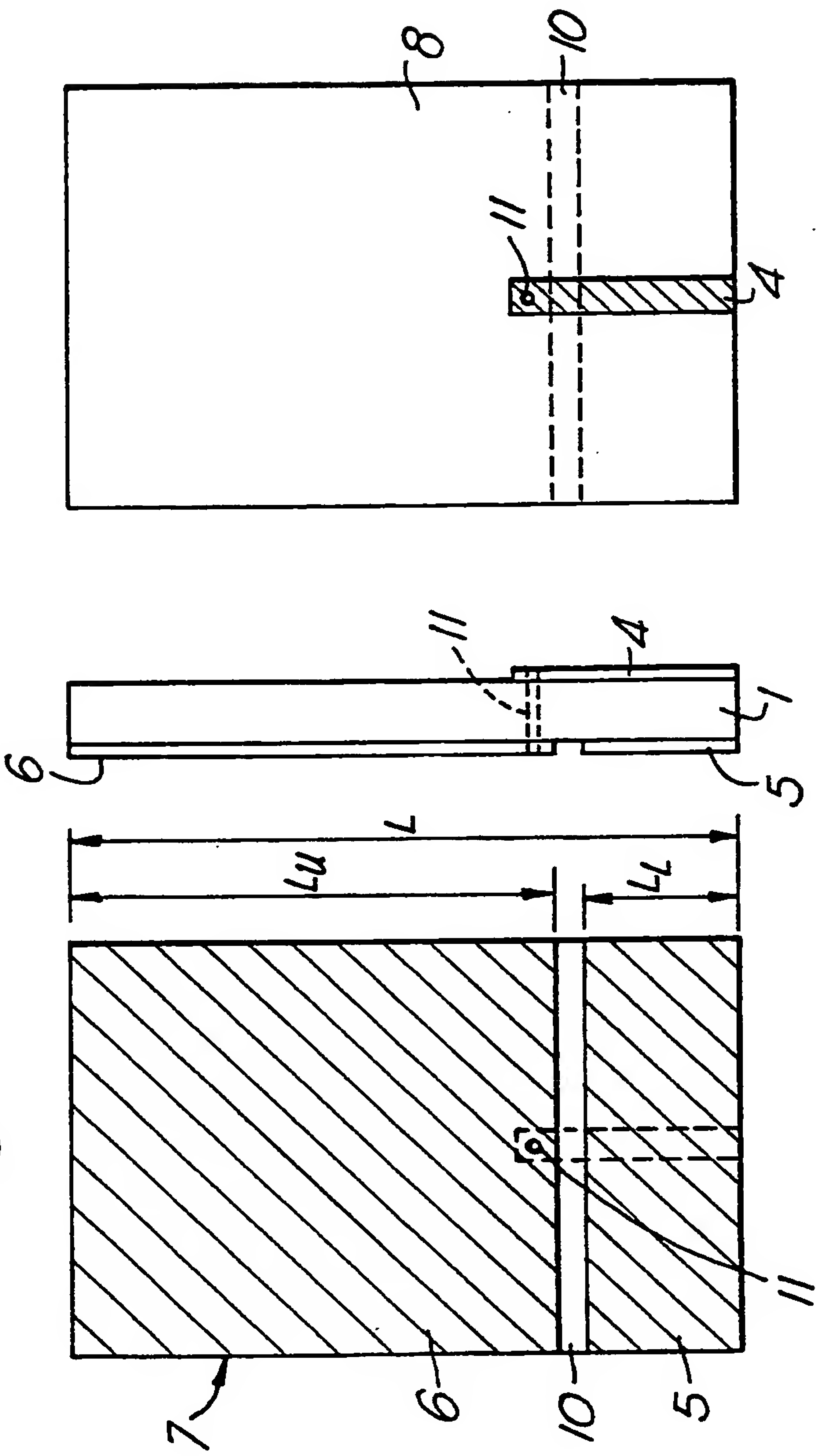
Fig.4.

Fig.5.



(a)
(b)
RELATIVE POWER (dB)
0
10
20
30
40
-180
-160
-140
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
120
140
160
180
ANGLE°

Fig. 6.



Monopole Antenna

This invention relates to a monopole antenna, that is, one having a radiating element extending orthogonally with respect to a surrounding ground plane.

The conventional monopole antenna comprising a resonant 'whip' or length of stiff wire extending vertically from a surrounding ground plane provides a useful omnidirectional radiation characteristic in the azimuthal plane above the ground plane. However, an inherent weakness of this antenna type is its narrow impedance match bandwidth. As a result, high efficiency cannot be achieved over a wide frequency bandwidth. The poor impedance match is a consequence of the reactive nature of the radiating element and generally limits the monopole antenna to use in narrowband applications. Where a broader bandwidth capability is required this is usually achieved by the use of complex impedance matching networks with the resultant extra cost and reduction in antenna efficiency.

It is an object of the present invention to provide a monopole antenna having a broader bandwidth capability than known designs.

According to the invention a monopole antenna comprises a ground plane, a radiating element disposed orthogonally with respect to the ground plane, and a feed line, the radiating element comprising a first conductive sheet connected to the ground plane, and a second conductive sheet remote from the ground plane, and the feed line comprising a conductive strip extending from the ground plane and connected to the second sheet, the first sheet of the radiating element also constituting an associated ground plane for the feed line.

The first and second conductive sheets and the conductive strip are preferably carried on a common dielectric substrate.

In a preferred embodiment of the invention, the first and second conductive sheets are formed on opposite main faces of the substrate, the conductive strip forming a continuous layer with the second sheet on one main face of the substrate.

In an alternative embodiment of the invention, the first and second conductive sheets are carried on one main face of the substrate and the conductive strip is carried on the opposite main face of the substrate.

In a preferred embodiment, the conductive sheets being spaced apart in a direction orthogonal to the ground plane, the combined dimension of the first sheet, the second sheet and the spacing between the sheets in a direction orthogonal to the ground plane constitutes a quarter-wavelength at a frequency within the operating bandwidth of the antenna.

A monopole antenna in accordance with the invention will now be described, by way of example only, with reference to the accompanying drawings, of which:

Figure 1 is an illustration of a monopole antenna in accordance with the invention;

Figure 2 shows detail of the antenna of Figure 1;

Figure 3 shows the return loss characteristics of (a) an antenna in accordance with the invention and (b) an equivalent conventional monopole antenna;

Figure 4 shows typical elevation radiation patterns in the two orthogonal principal planes of an antenna in accordance with the invention;

Figure 5 shows (a) co-polar and (b) cross-polar azimuth radiation patterns of an antenna in accordance with the invention; and

Figure 6 is an illustration of an alternative construction of an antenna in accordance with the invention.

Referring to the drawings, in Figure 1 a dielectric substrate 1 is mounted orthogonally, i.e. vertically as shown, on an extensive horizontal ground plane 2 (part shown) The ground plane 2 may be a sheet of aluminium or other conductive material. A radiating element supported by the substrate 1 comprises a first conductive sheet and a second conductive sheet, shown respectively as lower section 5 and upper section 6 in the figure. The thickness of the substrate 1 is shown exaggerated. The lower section 5 (part hidden) is carried on one main face 8 of the substrate 1, with the upper section 6 being carried on the opposite main face 7.

Figures 2(a) and 2(b) show respective views of the main faces 7 and 8 of the substrate 1. The conductive sheets are shaded for clarity. As viewed in Figure 2, the two sections 5 and 6 do not 'overlap' one another, but are spaced apart by a narrow slot 10, that is to say the sum of the length L_U of the upper section 6 and the length L_L of the lower section 5 is somewhat less than the overall length L of the substrate 1. The slot 10 is parallel to the ground plane 2 (not shown in Figure 2).

The lower section 5 of the radiating element is connected along one edge 9 (Figure 1) to the ground plane 2. The connection may be made, for example, by soldering and it may also serve to support the substrate in the vertical position. On the face 7 of the substrate, there is provided a narrow conductive strip 4, which, in combination with the lower section 5, forms a 'balanced' microstrip feed line for the antenna. Thus, the lower section 5 acts as an associated ground plane for the feed stripline 4 as well

as being a component of the radiating element. The strip 4 is electrically connected at one end and across the slot 10 to the upper section 6 to form a continuous conductive layer on the face 7 of the substrate. The other end of the strip 4 is connected through a hole (not shown) in the ground plane 2 (from which it is isolated) to the inner terminal of a coaxial-type connector (not shown) on the underside of the ground plane. The outer terminal is connected to the ground plane. The connector permits the coupling of a coaxial cable to feed the antenna.

The overall vertical length L of the radiating element is chosen to constitute a quarter-wavelength at a frequency, preferably the fundamental resonant frequency, within the operating bandwidth of the antenna. The length L_L of the lower section 5 is chosen to produce the required impedance match to the antenna feed and is made a relatively small proportion (say, less than 20%) of the overall length L. The extent of the horizontal ground plane 2 affects the radiation pattern, in particular the sidelobe levels. It is ideally infinite, but is generally made as large as practicable.

One realisation of an antenna in accordance with the invention was based on the following design parameters:

substrate - material RT Duroid	5880
- dielectric constant	2.5
- thickness	1.5mm
L	80mm
L_U	63mm
L_L	14mm
slot width	3mm
substrate width	37mm
feed stripline width	4.5mm
bandwidth (VSWR 2.5:1)	0.7 - 4 GHz

Figure 3 shows the return loss in dB (full line (a)) of an antenna according to the above design. The bandwidth is in excess of 5:1 for VSWR less than 2.5:1, i.e. better than -7.5dB return loss. On the frequency scale F_0 represents 0.5 GHz. Thus, for this design the operating frequency range of the antenna extends from approximately 0.7 to 4.0 GHz. The return loss for a conventional monopole whip antenna having a similar resonant length (70mm) is also shown in Figure 3 (dashed line (b)). The measurements for both antennas were made using a circular ground plane having a diameter of five wavelengths at a frequency of 1GHz.

Figure 4 shows the elevation radiation patterns for the same antenna design (Figures 1 and 2) in the two principal planes orthogonal to the ground plane 2.

Figure 5 shows the omnidirectional radiation patterns ((a) co-polarisation and (b) cross-polarisation) for the same antenna design in the azimuth plane parallel to the ground plane 2. The characteristics are centred at 0° on a line perpendicular to the plane of the substrate 1, as indicated by axis 3 in Figure 1. The cross-polarisation level is in excess of 18dB.

It is apparent from Figures 3, 4 and 5 that the antenna described provides substantially the same omnidirectional radiation pattern as the typical conventional monopole antenna, but with a superior impedance match bandwidth which is in excess of 5:1 with VSWR less than 2.5:1.

The azimuthal radiation pattern, particularly in the region adjacent the substrate face 7 carrying the feed strip 4, is degraded (i.e. becomes less symmetric about the plane of the substrate) by the thickness of the substrate, which should therefore be as thin as is possible while still providing a rigid support for the upper section 6 of the radiating element. Degradation of the radiation pattern also occurs at higher frequencies in the operating band due to the increase in the effective thickness of the dielectric substrate.

The improved impedance match bandwidth provided by the antenna is substantially due to the additional capacitance of the slot 10 at the feed point counterbalancing the inductance of the upper section 6 of the radiating element at the higher frequencies of the operating band. This effect extends the range of frequencies over which the antenna has an overall low input impedance, thus increasing the bandwidth.

In an alternative embodiment of the invention, the lower and upper sections 5, 6 of the radiating element are carried on the same face of the substrate 1, being separated as before by the narrow slot 10. Figure 6 shows views of the two main faces 7 and 8 of the substrate and a view of one vertical edge. The ground plane 2, which has been omitted, is the same as in Figure 1. The radiating element sections are both carried on face 7, whereas the feed strip 4 is carried on the opposite face 8. The feed strip 4 is connected at one end to the upper section 6 by means of a plated-through hole 11 in the substrate 1. As an alternative to the plated-through hole, a shorting pin (not shown) may be used. The connection, however formed, is made at a point on the upper section 6 close to the slot 10. Performance of this construction of the antenna is substantially the same as for the Figure 1 design.

In both embodiments of the invention described above, it can be seen that the radiating element and feed line may be conveniently fabricated using microstripline circuit board. However, the first described embodiment (Figures 1 and 2) is preferred for its ease of fabrication, since there is no requirement here to make a connection through the substrate between the feed line strip 4 and the upper radiating section 6.

Claims

1. A monopole antenna comprising a ground plane, a radiating element disposed orthogonally with respect to the ground plane, and a feed line, said radiating element comprising a first conductive sheet connected to the ground plane, and a second conductive sheet remote from the ground plane, and said feed line comprising a conductive strip extending from the ground plane and connected to the second sheet, the first sheet of the radiating element also constituting an associated ground plane for the feed line.

2. A monopole antenna according to Claim 1, wherein said first and second conductive sheets and said conductive strip are carried on a common dielectric substrate.

3. A monopole antenna according to Claim 2, wherein said first and second conductive sheets are carried on opposite main faces of said substrate, said conductive strip forming a continuous layer with said second sheet on one main face of the substrate.

4. A monopole antenna according to Claim 2, wherein said first and second conductive sheets are carried on one main face of said substrate and said conductive strip is carried on the opposite main face of the substrate.

5. A monopole antenna according to Claim 3 or Claim 4, wherein said conductive sheets are spaced apart in a direction orthogonal to said ground plane, the combined dimension of said first sheet, said second sheet and the spacing between the sheets in a direction orthogonal to the ground plane constituting a quarter-wavelength at a frequency within the operating bandwidth of the antenna.

6. A monopole antenna according to any preceding claim, wherein the connection between said first sheet and said ground plane is made along an edge of the first sheet.

7. A monopole antenna substantially as hereinbefore described with reference to Figure 1 and Figure 2 or to Figure 6 of the accompanying drawings.

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